
Winchmore long-term fertiliser trial: 2021-2022 annual update

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1. Executive Summary

The Winchmore long-term fertiliser trial was set up in 1952 to measure the response of pasture production to increasing rates of phosphorus (P) fertiliser. Fertiliser treatments included no P (control), 188, 250 and 376 kg of single superphosphate (SSP) ha⁻¹ yr⁻¹ and 175 ha⁻¹ yr⁻¹ Sechura reactive rock phosphate (RPR)/elemental Sulphur (S). This report summarises the results of soil and pasture monitoring from the trial undertaken for the 2021 – 2022 season.

Pasture production was measured ten times over the season, using the rate of growth technique with movable pasture cages. Dry matter (DM) production on the four fertiliser treatments averaged 14,000 kg DM ha⁻¹, slightly higher than the long-term annual average (c.12,000 kg DM ha⁻¹). Dry matter production for the no P treatment was significantly less at 5,500 kg DM ha⁻¹. Pasture was dominated by grass species, with lesser amounts of clover and weeds. There was a notable increase in the amount of clover present (about 20%) in mid-summer.

Compared to the no P treatment, the application of P fertiliser had no significant ($P < 0.05$) effect on magnesium (Mg), potassium (K), and sodium (Na) concentrations or soil pH. There has been a slow decline in soil pH since the last application of lime in 1975 until the early 1990's, although pH has remained reasonably consistent (between 5.7 and 5.9) since. Calcium (Ca) was significantly higher in the fertilised treatments compared to the no P treatment. Probably a result of the input of Ca that along with P is contained in both the SSP and RPR fertiliser. The application of fertiliser resulted in an increase in sulphate-S concentrations in the fertiliser treatments, that remained within or slightly above the recommended range across the year in all the fertiliser treatments. Olsen P concentrations in the fertiliser treatments were significantly higher ($P < 0.05$) than the no P treatment. Olsen P concentrations have increased over the last 20 years, particularly in the 375 SSP treatment which has increased from about 50 to 85 µg mL⁻¹.

The relationship between soil Olsen P and relative pasture yield under spray irrigation was higher than that previously measured under border-dyke irrigation, indicating the possibility of a different relationship between the two types of irrigation systems. More data collected over the next few years is still required to confirm this hypothesis.

2. Background

The Winchmore long-term fertiliser trial commenced in 1952. The initial aim of the trial was to establish the response of pasture ryegrass (*Lolium spp*) and white clover (*Trifolium repens*) production ($\text{kg ha}^{-1}\text{yr}^{-1}$) and productivity (production per unit of phosphorus (P) input) to increasing rates of P fertiliser applied as single superphosphate (SSP) or reactive phosphate rock (RPR). However, the trial has been used extensively by many researchers over the last 40 years for a wide variety of studies including soil carbon (C), nitrogen (N), P, potassium (K) and sulphur (S) chemistry, nutrient cycling, effects of P fertiliser on earthworm numbers, as well as on dichloro-diphenyl-trichloroethane (DDT), cadmium (Cd) and fluorine (F) residue research.

Research on the trial has resulted in several hundred scientific publications and has been used in the development and validation of several models including OVERSEER®, Farmax and CadBal. The Winchmore trial was highlighted in a special edition of the New Zealand Journal of Agricultural Research in 2012 (Smith et al. 2012) and more recently in a data descriptor paper in Nature Scientific Reports (McDowell et al. 2021).

This report summarises the results from the annual soil and pasture monitoring programme undertaken at the trial over the 2021 – 2022 year.

3. Materials and Methods

1.1 Trial setup and management

The trial has 20 plots (0.09 ha), divided into five treatments each with four replicates arranged in a randomised block design. The treatments applied annually since 1952 include 0 (no P), 188 and 375 kg ha^{-1} of single superphosphate (SSP). Since 1980, there has also been a 250 $\text{kg ha}^{-1} \text{yr}^{-1}$ SSP treatment, and a Sechura RPR/S treatment applied annually at 22 kg P ha^{-1} (equivalent to 250 kg SSP ha^{-1}).

The SSP treatments received their fertiliser on 6th July 2021 and RPR/S on the 13th of September 2021. As in previous years, SSP fertiliser was applied using a farm drill with the down tubes removed. To avoid the risk of applying too much fertiliser, the drill was calibrated to apply less fertiliser than required and the deficit applied by hand. The RPR/S application was applied by hand with the S sieved through a 2 mm screen prior to being applied. The RPR was supplied by Ravensdown and contained 13% total P, 5.2% citric acid soluble P, 8.0% formic acid soluble P, 30% calcium and a maximum of 280 mg Cd kg^{-1} P. Subsamples of the SSP, RPR and S fertiliser applied to the trial have been retained.

The plots were grazed by separate mobs of sheep that rotated between replicates within treatments from September to May. Stocking rates were adjusted during the year with the aim of achieving a post-grazing residual herbage mass height of approximately 30 mm.

Between 1952 to 2018, the trial received on average 4.3 irrigation events (100 mm per event) per annum using border-dyke irrigation. In 2019, the trial was converted from border-dyke to overhead spray irrigation. Irrigation water is applied via a variable rate-controlled centre pivot irrigator. Irrigation is managed in cooperation with the farm owner. The aim of the irrigation is to apply sufficient water to ensure the soil moisture level is maintained above 50% of field capacity up to a maximum of 90% of field capacity. A NIWA operated “irrigation insight” climate station has been installed at a mid-point on plot five, recording at 2-hourly intervals, soil moisture, soil temperature and irrigation water applied to the trial. Rainfall was measured at a NIWA climate station located on the adjacent farm. This data is used to calculate potential evapo-transpiration enabling the calculation of soil moisture deficits.

1.2 Sampling and analysis

Pasture production was measured using the rate of growth technique using two movable pasture exclusion cages (3.25 m long × 1.02 m wide) per plot (Radcliffe 1974; Lynch 1960). Areas within each cage were trimmed to 25 mm above ground level and left for a standard grazing interval for that time of year. Following each grazing interval, a lawnmower was used to harvest a 0.52 m wide strip in the middle of each enclosure to 25 mm above ground level. The wet weight was determined, and a sub-sample taken to determine dry matter percentage. A separate sample was manually dissected into grass, clover and weeds to determine botanical composition of the pasture five times over the growing season in September, November, January, March and April, using the method described in Lynch (1966). Subsamples of grass and clover have been retained for future chemical analysis.

A composite soil sample of 14 cores (2.5 cm diameter and 7.5 cm deep) was collected from each plot four times, in July, prior to fertiliser application, and in October, January, and April. Cores were taken at random following a diagonal route from end to end of each plot. The surface pasture/thatch was removed from samples before the soils were air-dried, sieved to 2 mm and analysed at a commercial laboratory for soil pH, exchangeable cations Ca, Mg, K, Na, Olsen P and sulphate-S. After laboratory analysis a subsample of soil has been retained.

4. Results and Discussion

4.1 Irrigation scheduling

In total, 657 mm of rainfall was recorded at the trial site for 2021 – 2022, 12% lower than the long-term annual average of 745 mm. There was 235 mm of irrigation applied between early September 2021 through to late April 2022. This compares with the approximately 350 to 400 mm of irrigation that was typically applied under the flood irrigation system previously used at the trial site. Irrigation was applied on 29 occasions at rates between 2 to 18 mm (Figure 1).

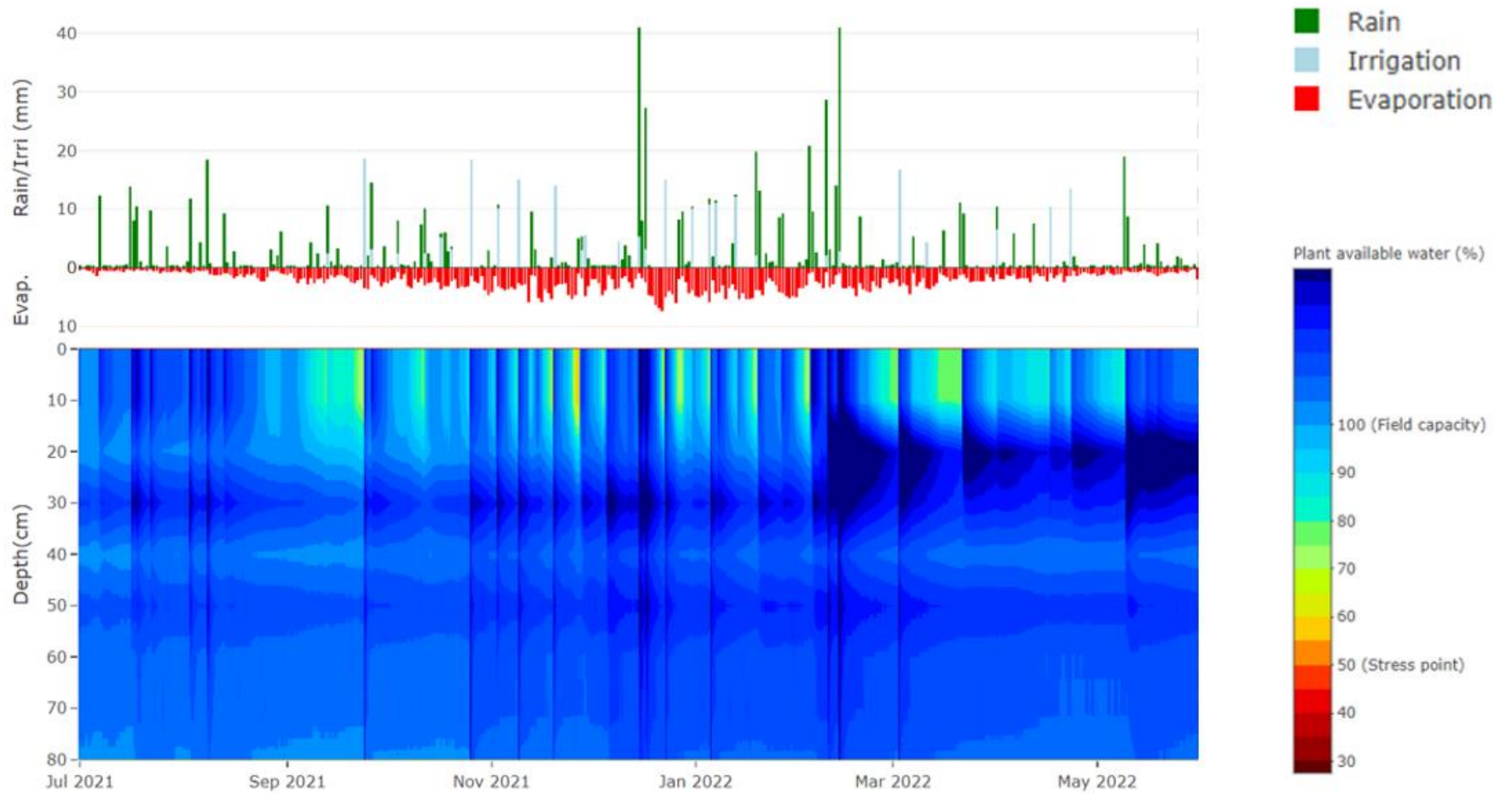


Figure 1. Daily rainfall (mm), irrigation (mm), evaporation (mm) (top panel) and soil moisture (%) (lower panel) at the Winchmore long term fertiliser trial over the 2021-2022 season.

As noted, the protocol for irrigation management states that irrigation water will be applied when the topsoil moisture drops to 50% of field capacity (FC), at which time sufficient water will be applied to return the soil moisture level to about 90% of FC. Figure 1 shows that soil moisture was maintained around this target for much of the year, except for brief periods after heavy rainfall where it exceeded this target.

4.2 Pasture production

Pasture was harvested on ten occasions between early September 2021 and the end of May 2022. Dry matter (DM) yields were significantly greater from the fertiliser treatments than the control (Table 1; Figure 2). Despite different rates of P fertiliser, there was no significant difference in DM yield between the four fertiliser treatments (Table 1), which averaged c. 14,000 kg ha⁻¹, slightly higher than the long-term average for the trial of c. 12,000 kg ha⁻¹ (Figure 2).

Table 1: Seasonal and annual pasture production from the irrigated Winchmore long-term fertiliser trial for 2021-2022 (kg DM ha⁻¹). The least significant difference (LSD) at the P<0.05 level is given along with the F-statistic for comparison of treatment means (bold if significant). Note the Ex. No P comparison covers the applied fertiliser treatments only.

Treatment	Spring	Summer	Autumn	Total
No P	1609	1823	2072	5503
188 kg SSP ha ⁻¹	4444	4967	3877	13288
250 kg SSP ha ⁻¹	4654	5791	4461	14908
175 kg RPR ha ⁻¹	4404	5098	4478	13981
375 kg SSP ha ⁻¹	4663	5352	4554	14569
All LSD _{0.05}	620	821	982	1954
All F-Statistic	<0.001	<0.001	<0.001	<0.001
Ex. No P LSD _{0.05}	0.718	0.267	0.511	0.402
Ex. No P F-Statistic	647	931	1099	2178

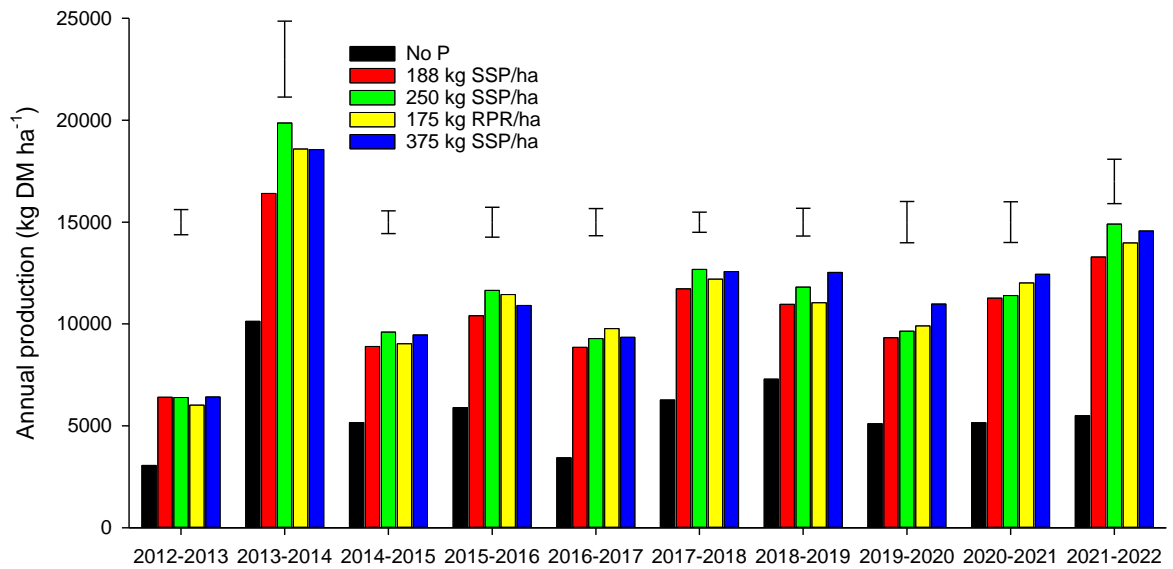


Figure 2. Annual pasture production over 10 years for the long-term irrigated fertiliser trial at Winchmore (kg DM ha⁻¹). Bars indicate LSD (P<0.05).

As expected, daily pasture growth rates increased in spring before peaking in mid-summer (Figure 3). Although there was a small unexplained dip in the 375 SSP and 175 RPR treatments in mid-December. Except for September, daily pasture growth rates were significantly greater in the fertiliser treatments than the control.

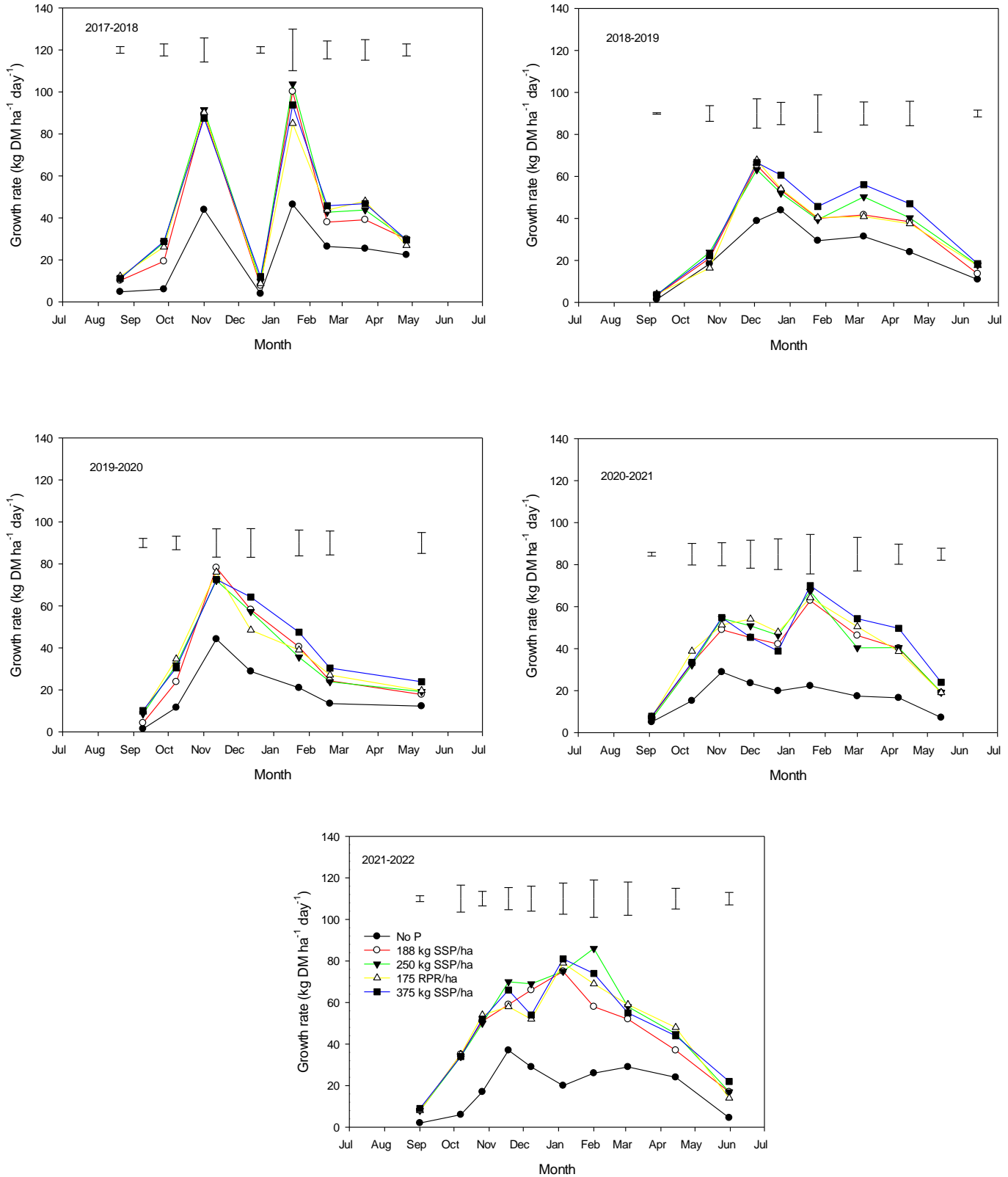


Figure 3. Daily pasture growth over five years for the long-term irrigated fertiliser trial at Winchmore (kg DM ha⁻¹ day⁻¹). Bars indicate LSD (P<0.05). NB the growth rate shown is the daily growth rate from the previous measurement to the date shown in the graphs.

4.3 Species composition

In line with previous years, pasture was dominated by grass species throughout the year, with lesser amounts of clover and weeds (Table 3). Over the warmer months however there was a notable increase in the proportion of clover across all treatments. Interestingly, there have been several incidences over the last 30 years where clover has declined to low levels and then recovered the following year in the summer months (Figure 4).

Table 3: Seasonal and treatment effects on pasture species fractions from the Winchmore long-term irrigated fertiliser trial for 2021-2022 (% species present on a dry matter basis). The least significant difference (LSD) at the $P < 0.05$ level is given along with the F -statistic for comparison of treatment means (bold if significant).

Treatment	1/9/21			18/11/21			5/1/22			3/3/22			15/4/22		
	Grass	Clover	Weeds	Grass	Clover	Weeds	Grass	Clover	Weeds	Grass	Clover	Weeds	Grass	Clover	Weeds
No P	96.4	2.5	1.1	93.8	5.5	0.8	82.1	10.8	7.0	92.7	5.8	1.5	90.3	7.0	2.7
188 kg SSP ha ⁻¹	98.0	1.8	0.1	89.7	9.3	1.0	83.1	15.8	1.1	84.8	13.4	1.8	91.7	7.3	1.0
250 kg SSP ha ⁻¹	96.3	3.2	0.5	88.3	10.9	0.8	73.0	26.4	0.7	84.0	15.1	0.9	95.1	4.4	0.5
175 kg RPR ha ⁻¹	98.5	1.5	0.0	93.5	5.6	0.9	78.5	21.3	0.2	89.2	10.5	0.3	97.4	2.4	0.3
375 kg SSP ha ⁻¹	99.2	0.8	0.1	96.2	3.1	0.7	88.0	11.2	0.8	79.2	19.1	1.7	91.6	7.9	0.5
All LSD 0.05	4.435	3.505	1.553	6.13	0.095	1.799	13.22	13.99	5.08	9.92	10.21	2.170	3.761	3.154	2.019
All F-Statistic	0.554	0.622	0.546	0.088	0.135	0.998	0.215	0.134	0.065	0.091	0.123	0.558	0.009	0.014	0.066

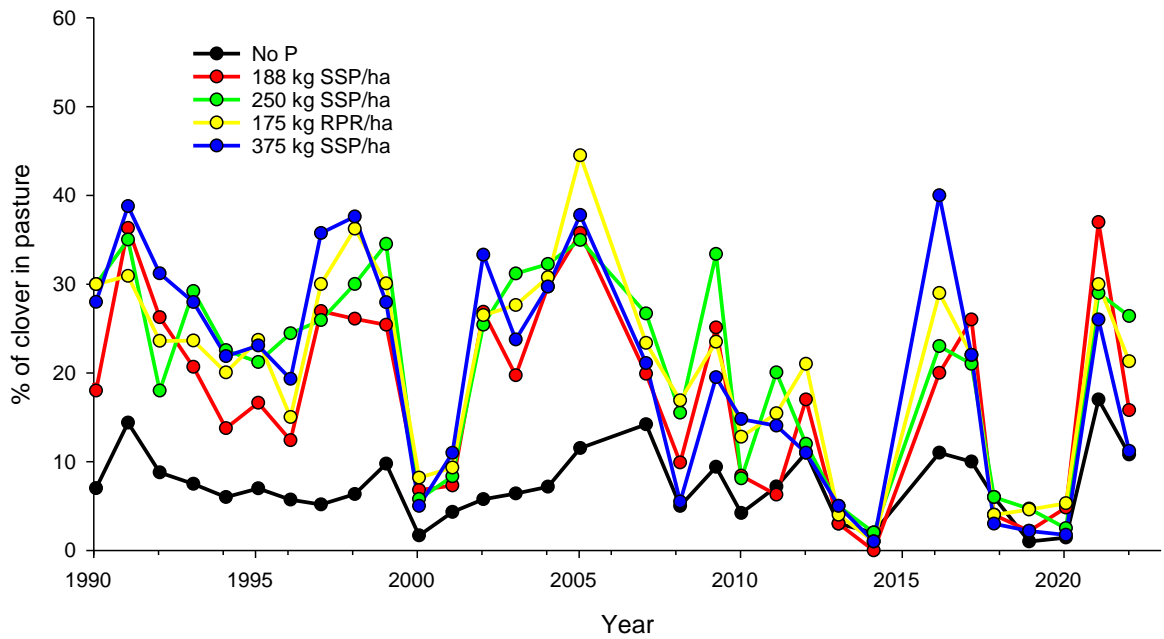


Figure 4. Long term effect of phosphate fertiliser application on clover content (%) over the summer from the Winchmore long-term irrigated fertiliser trial.

4.4 Soil analysis

Soil samples were analysed four times over the 2021 – 2022 season, in July prior to the application of P fertiliser and again in October, January and April. The application of P fertiliser had no significant effect on soil pH, Mg, K, or Na concentrations (Table 4).

Table 4: Soil test results from the Winchmore long-term irrigated fertiliser trial for the 2021-2022 season. The least significant difference (LSD) at the $P < 0.05$ level is given along with the F-statistic for comparison of treatment means (bold if significant).

Treatment	pH	Ca (QT)	Mg (QT)	K (QT)	Na (QT)	Olsen P ($\mu\text{g mL}^{-1}$)	SO ₄ -S ($\mu\text{g mL}^{-1}$)
July 2021							
No P	5.8	9	24	13	4	7	5
188 kg SSP ha ⁻¹	5.7	10	24	13	5	27	6
250 kg SSP ha ⁻¹	5.8	11	24	10	5	42	5
175 kg RPR ha ⁻¹	5.7	10	24	13	5	37	7
375 kg SSP ha ⁻¹	5.6	11	21	10	4	85	5
LSD 0.05	0.1	1	4	4	0.5	8	1.2
F-Statistic	0.010	0.003	0.373	0.302	0.091	<0.001	0.006
October 2021							
No P						5	5
188 kg SSP ha ⁻¹						21	15
250 kg SSP ha ⁻¹						36	57
175 kg RPR ha ⁻¹						27	10
375 kg SSP ha ⁻¹						79	22
LSD 0.05						7	24
F-Statistic						<0.001	0.005
January 2022							
No P						4	6
188 kg SSP ha ⁻¹						27	18
250 kg SSP ha ⁻¹						42	13
175 kg RPR ha ⁻¹						33	15
375 kg SSP ha ⁻¹						92	16
LSD 0.05						7	5
F-Statistic						<0.001	0.004
April 2022							
No P						7	7
188 kg SSP ha ⁻¹						29	14
250 kg SSP ha ⁻¹						42	10
175 kg RPR ha ⁻¹						35	15
375 kg SSP ha ⁻¹						92	14
LSD 0.05						7	5
F-Statistic						<0.001	0.017

In line with the results found in previous years, K concentrations were slightly higher than the recommended range (5 – 8) for pasture sites grazed by sheep in New Zealand (Morton and Roberts 2018). Magnesium was about double the recommended concentration range (8 – 10) for pasture growth, although slightly below the recommend concentration for ewes in spring of 25 to 30 (Morton and Roberts 2018).

Soil pH was at the lower end or slightly below the recommended range (5.8 – 6.0). There has been a slow decline in soil pH since the last application of lime at the site in 1975 until the early 1990's (Figure 5). Although with the exception of 2007, 2010 and 2016, soil pH has been remained reasonably consistent between 5.7 and 5.9.

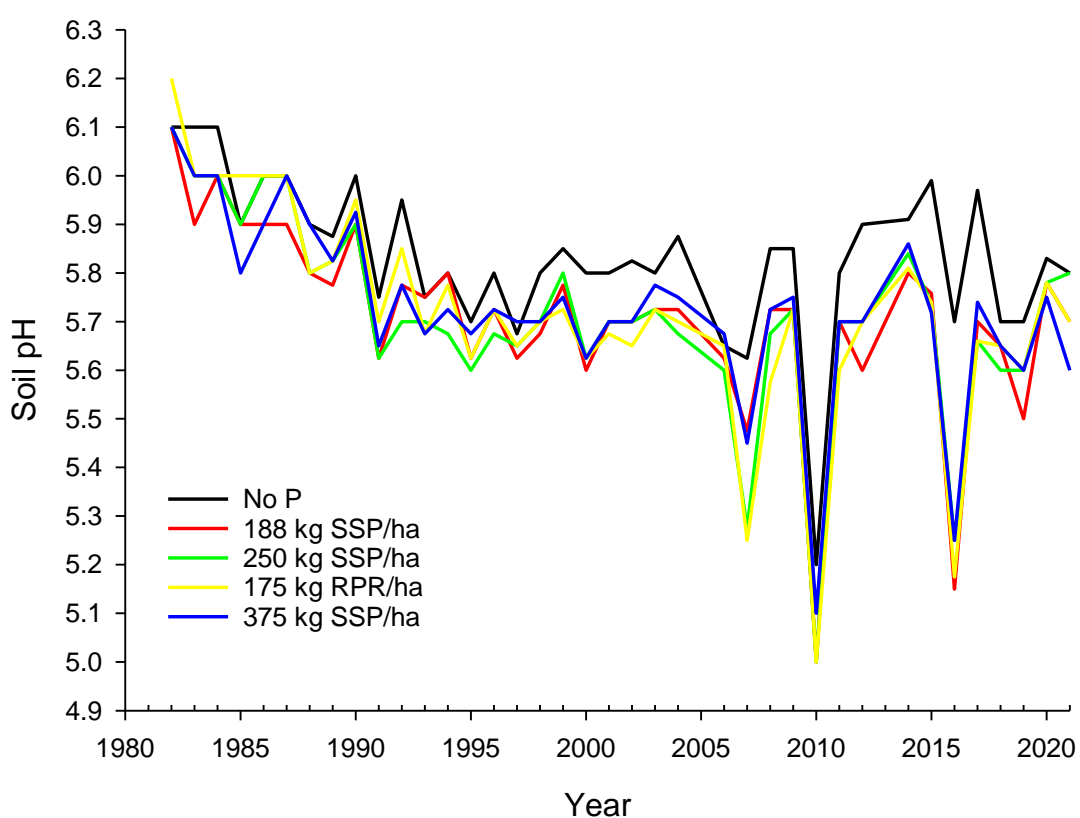


Figure 5: Soil pH values (0 – 75 mm depth) measured in winter each year from the long-term irrigated fertiliser trial at Winchmore.

Calcium was significantly higher in the fertilised treatments compared to the no P treatment (Table 4). This is probably a result of the input of Ca that along with P is contained in both the SSP and RPR fertiliser.

The application of fertiliser resulted in an increase in sulphate-S concentrations in the fertiliser treatments (Table 4). Surprisingly, the largest increase was in the 250 SSP treatment due to two very high sulphate-S concentrations (92 and $81 \mu\text{g mL}^{-1}$) in two of the four plots. It is unclear why there were high concentrations in these plots as their concentrations were normal three months later, (8 and $11 \mu\text{g mL}^{-1}$ respectively) as were their corresponding Olsen P concentrations throughout. Sulphate-S concentrations remained within or slightly above the recommended range ($10 - 12 \mu\text{g mL}^{-1}$) (Morton and Roberts 2018) across the year in all fertiliser treatments.

Olsen P concentrations in the fertiliser treatments were significantly higher than the no P treatment at all four sampling dates. Olsen P concentrations were largely within the recommended range ($20 - 30 \mu\text{g mL}^{-1}$) (Morton and Roberts 2018) across the year for the 188 SSP treatment, or above for the 250 SSP and 175 RPR treatments. In comparison, Olsen P concentrations were about three-fold higher than the recommended range in the 375 SSP treatment.

There has been a steady increase in Olsen P concentrations over the last 20 years, particularly in the 375 kg SSP treatment which has increased from about 50 to $85 \mu\text{g mL}^{-1}$ (Figure 6).

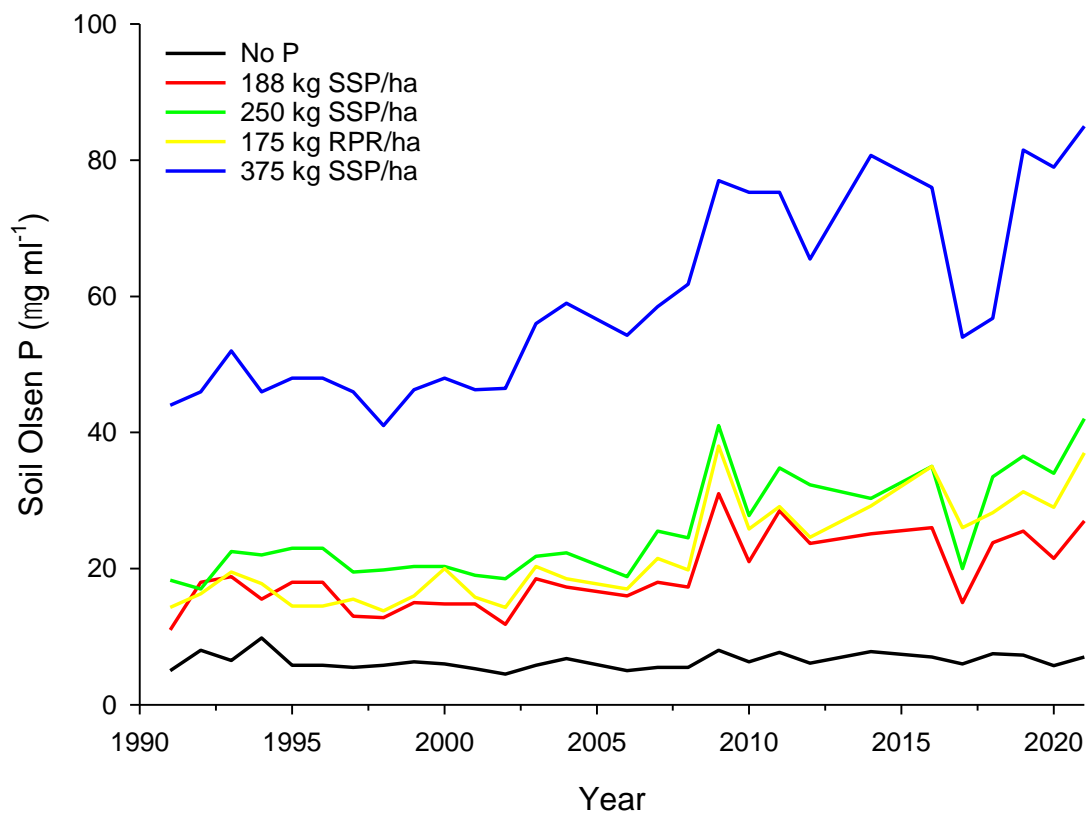


Figure 6: Soil Olsen P concentrations (0 – 75 mm depth) measured in winter each year, prior to the annual fertiliser application, from the long-term irrigated fertiliser trial at Winchmore.

5. Response curve

Using the methodology of Sinclair et al. (1997), it was possible to use data from 24 of the 37 years over the 1981 to 2018 period to derive a long-term response curve between Olsen P and relative pasture yields under border-dyke irrigation. The relative yields from this year's production are above the long-term response curve for all of the fertilised treatments (Figure 7). This may indicate a different response curve to Olsen P under spray irrigation to that previously measured under border-dyke irrigation. However, several years' more pasture yield data is still required to confirm this hypothesis.

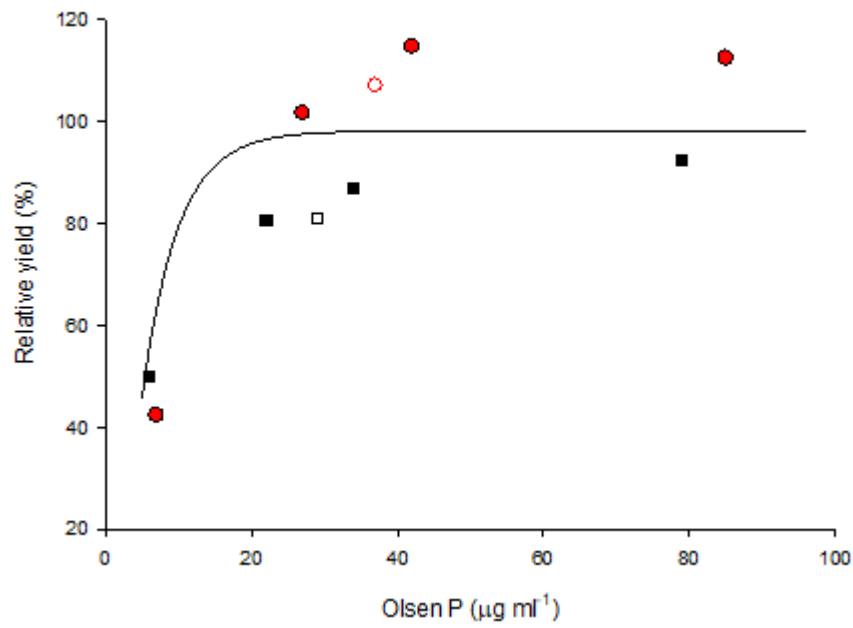


Figure 7. Relative pasture yields for the No P and SSP ● and RPR treatments ○ for the 2021-2022 season and No P and SSP ■ and RPR treatments □ for the 2020-2021 season. The solid line is the long term (1981-2018) pasture response curve.

6. Acknowledgements

We would like to acknowledge Chris Olley the farm owner for irrigation management and access to the site, the Lincoln farm team for stock management and the Fertiliser Association of New Zealand for their continued funding of this trial.

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